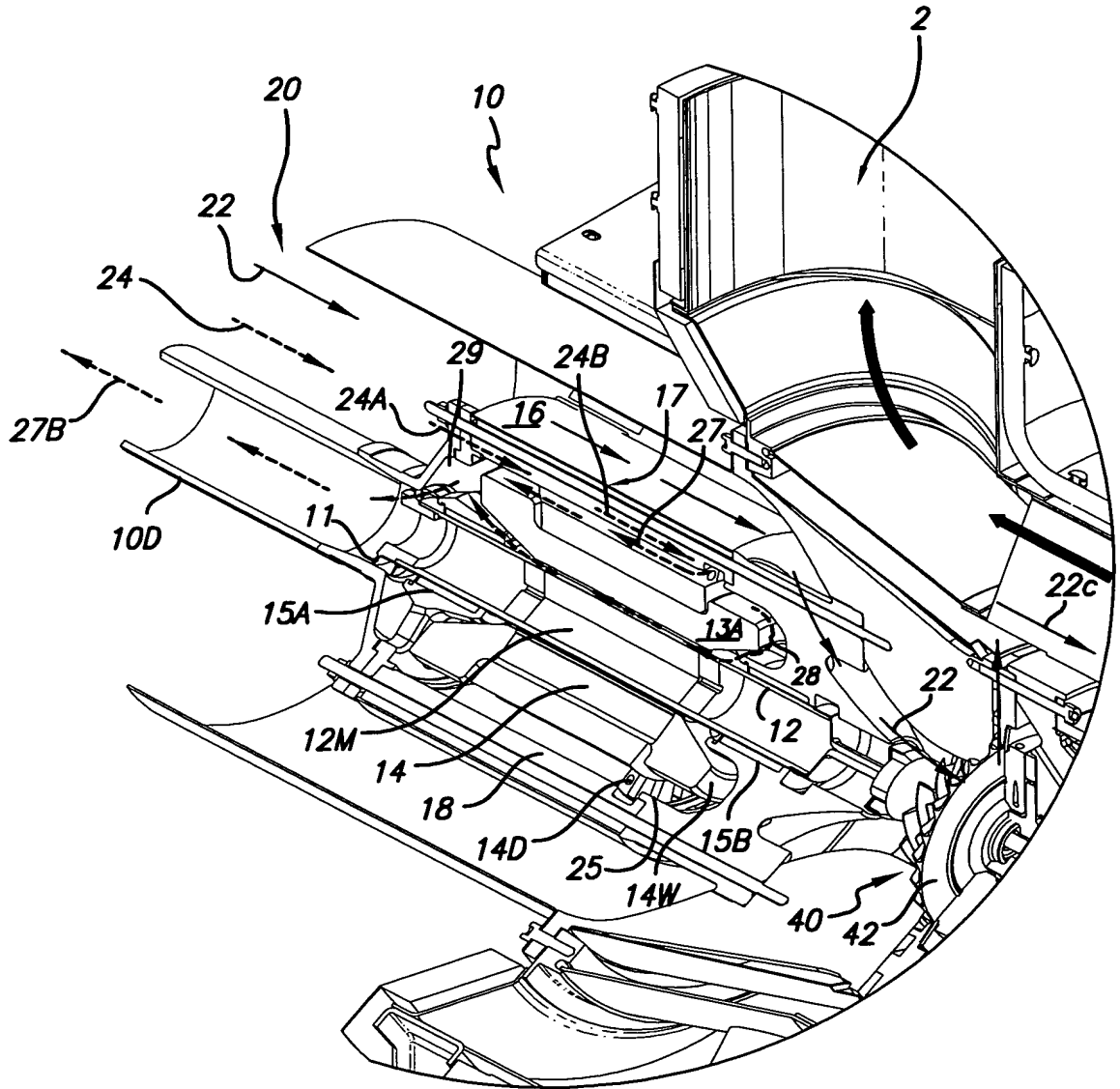FIG. 1A

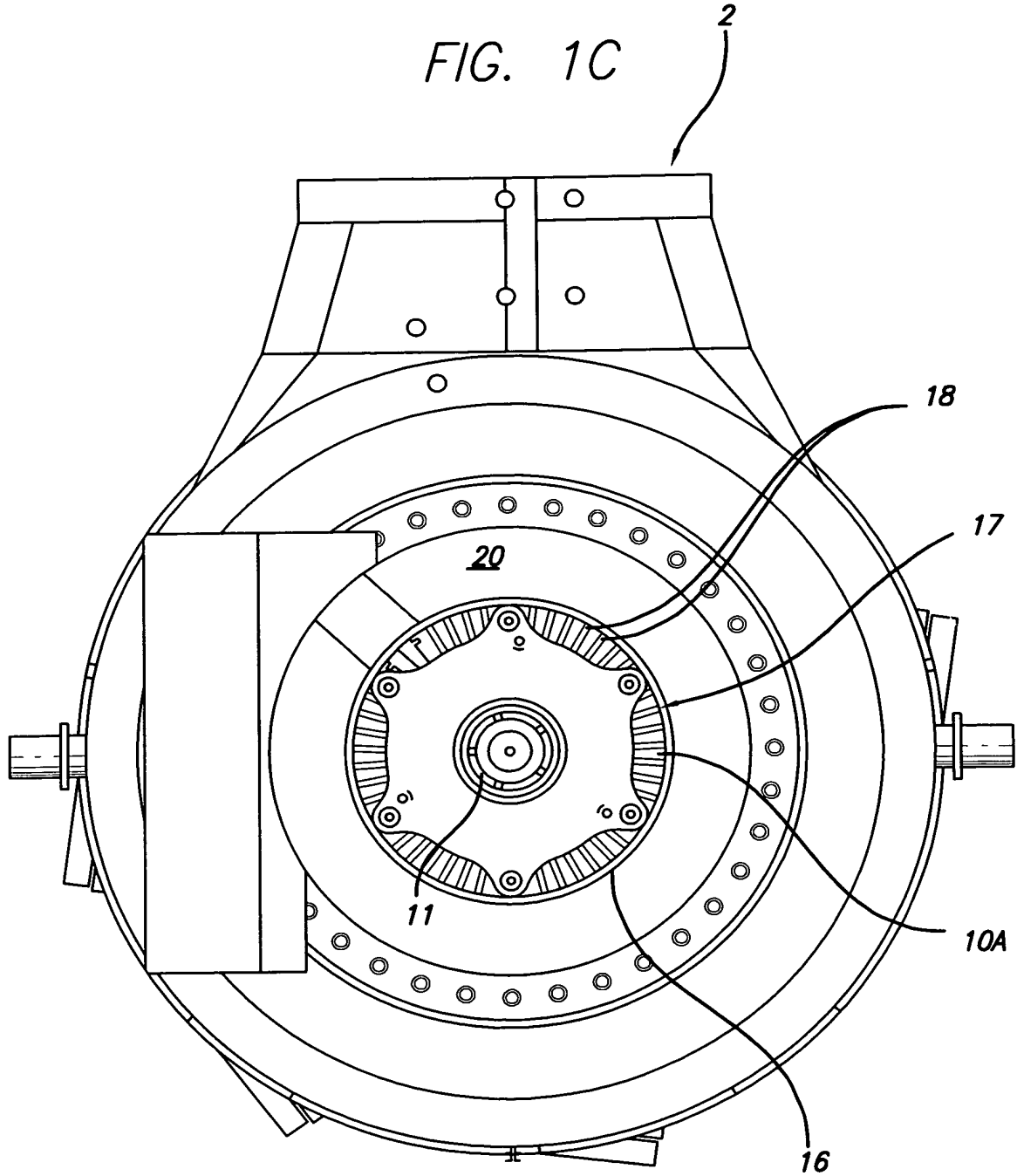# FIG. 1B

FIG. 1C

FIG. 1D

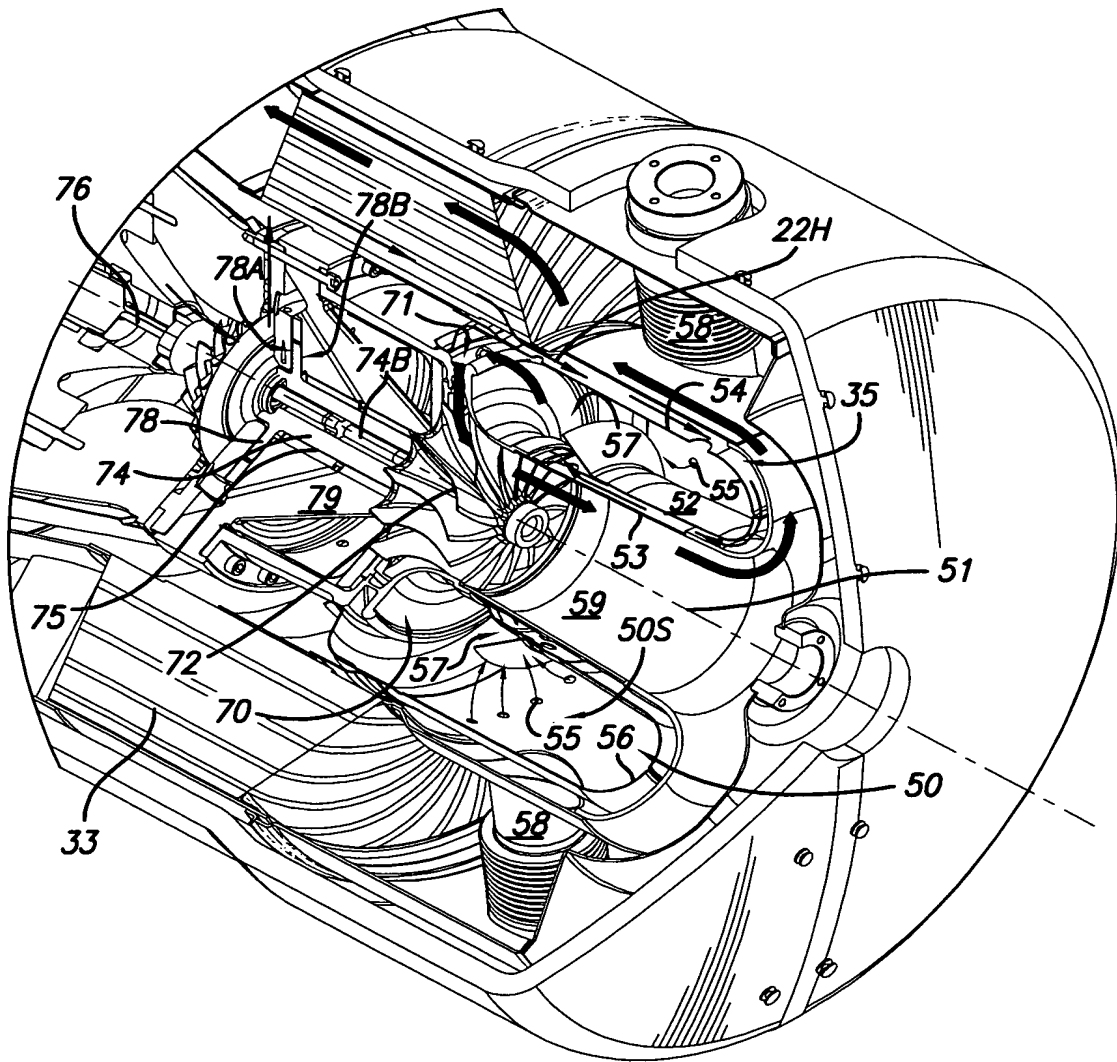FIG. 1E

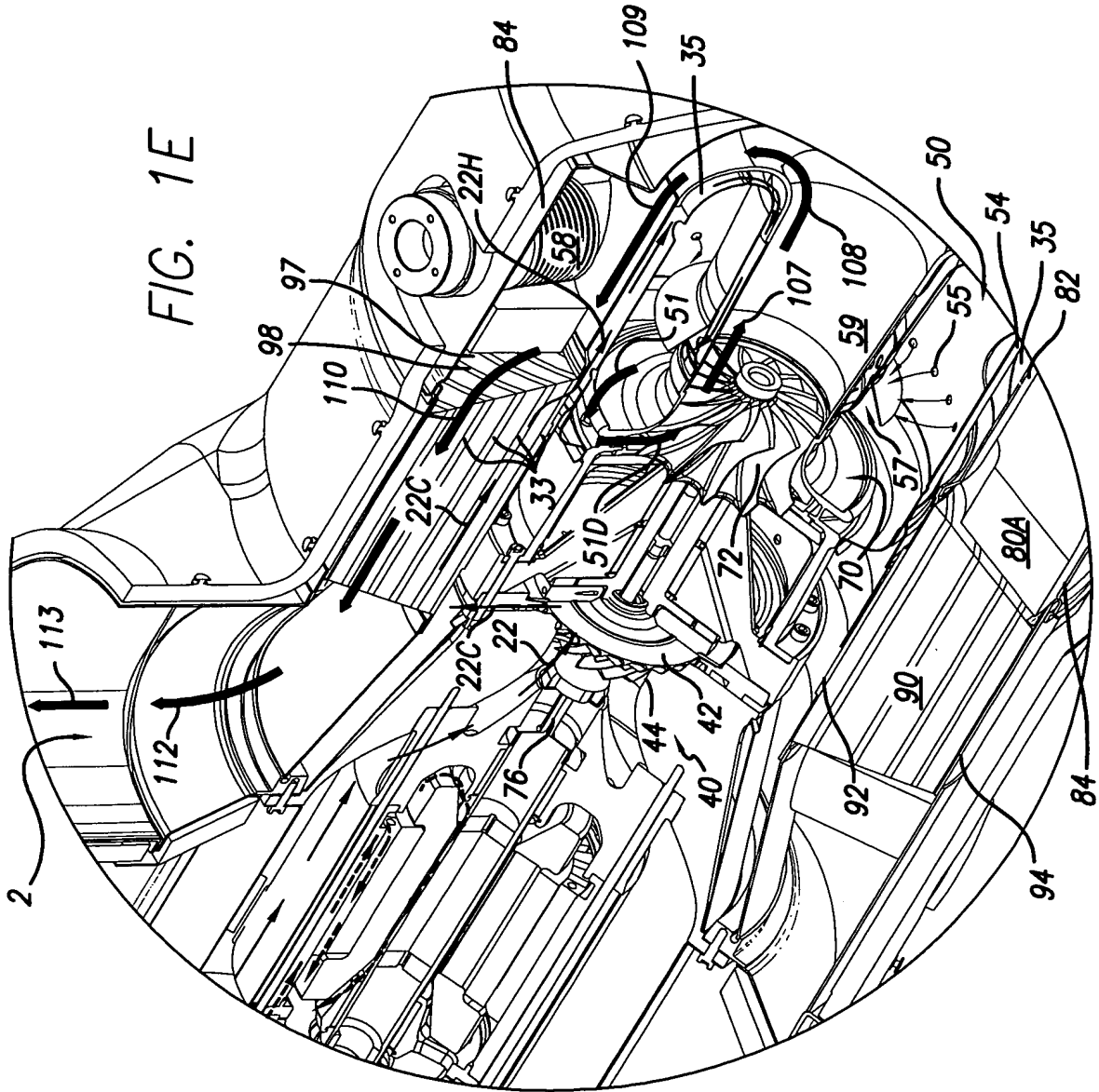# Fig. 2

200

Turbogenerator 1

Low Pressure Path

Optional Catalytic Reactor 80A

230

Fuel Ctrl.

50P

Primary Combustor 50

Recuperator 90

Exhaust 113

22C

Hi Pressure Path

Compressor 40

76

Turbine 70

226S

Motor/ Generator 10

203

Measured Temperature 226

Temp. Controller

228C

Load/ Grid 208

Bi-Directional Load Power Converter 206

Bus Voltage Controller 234C

Dynamic Brake Resistor 214

T* 232

V* 238 228

Measured Voltage 236

DC Bus 204

240

Bi-Directional Battery Power Converter 212

Energy Storage Device 210

244

242

Bi-Directional Generator Power Converter 202

Rotor Speed Controller 216C

222

w* 218

P* 224

220 216

Power Controller 201

302

generator

306

Utility Grid
Power

308

Distribution
Transformer

Local
Loads

304

Figure 3

electric power system

source of generation — *325*

326

330

320

322

318

328

316   310   312

generator   load

EPS site #1

324

EPS site #2

314

load

FIGURE 4

FIGURE 5

340

341 *342*

356

3 phase voltage
measurements

```
[ Measure       ]        [ Low pass ]          Angular
[ angular       ]------->[ filter   ]--------> frequency
[ frequency     ]                              estimate
```

358

344 *346* *348*

```
[ Measure ]      +  /‾‾‾\        [ Phase       ]     +    +
[ angle   ]-------> (     )----->[ correction  ]--------> /‾‾‾\
                \___/            [ gain        ]         (     )
                  -                                       \___/
```

350

Angle
estimate, θ

```
        <-------------------+        [ Integrator ]
                            |        [            ]<----------
```

354 *352*

Figure 6

V_{POC_Island}

I_{POC_Island}

PLL output
angle, θ

ϕ_{Island} δ

θ

Stationary
reference axis

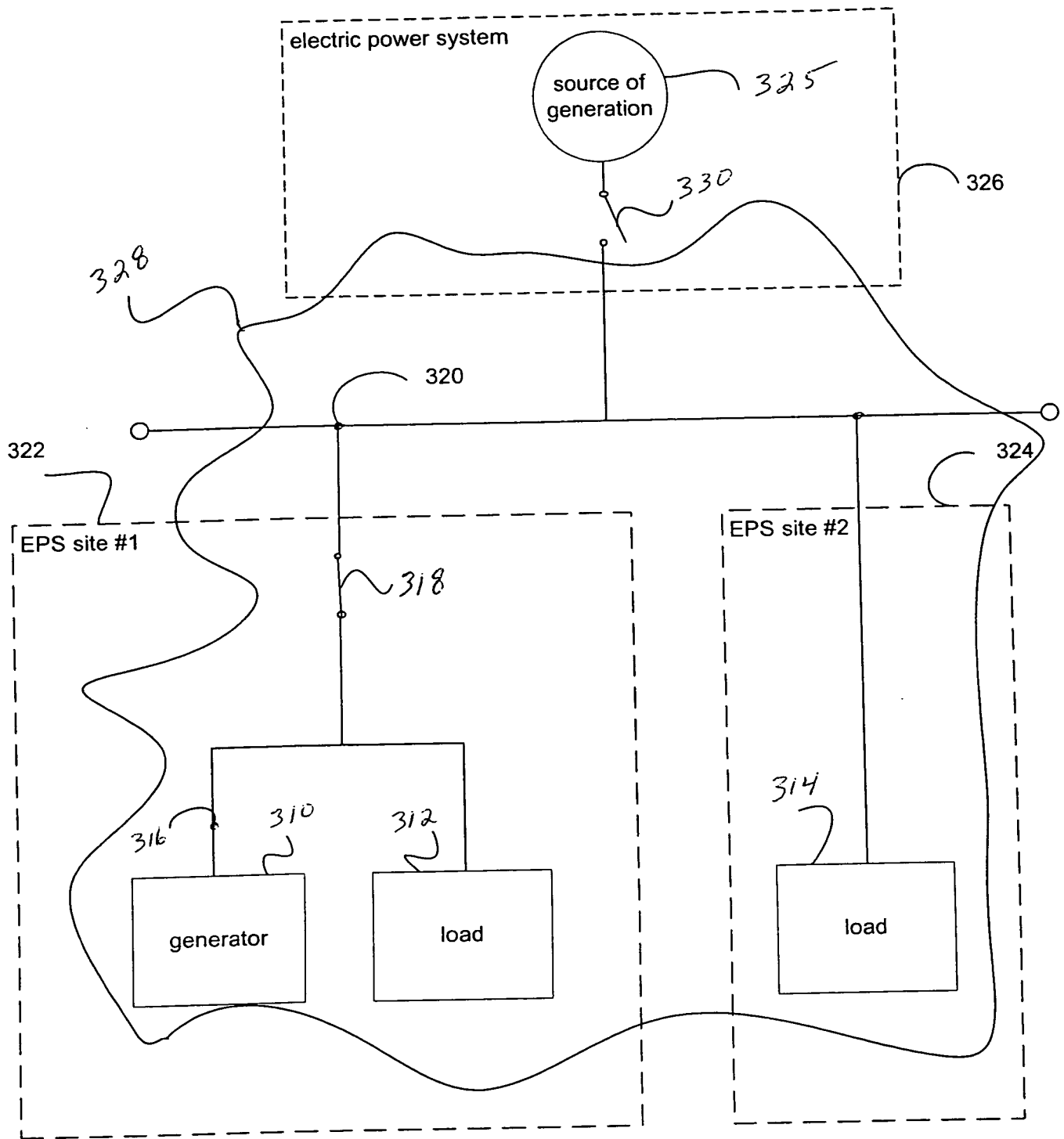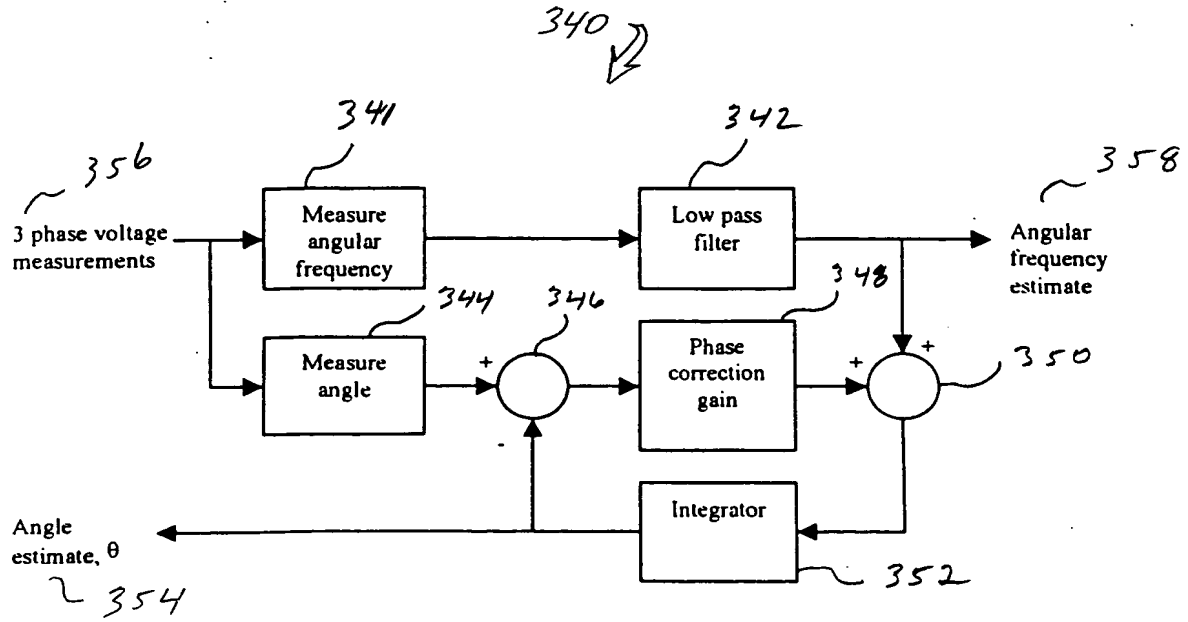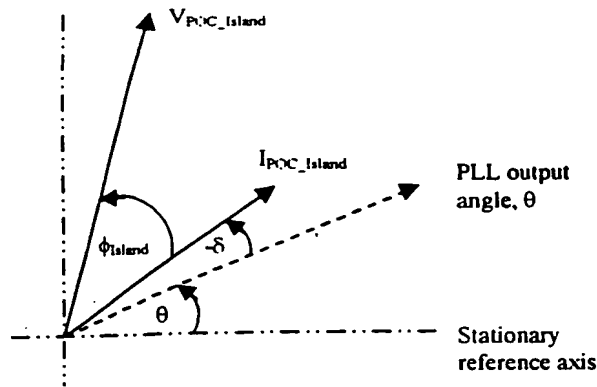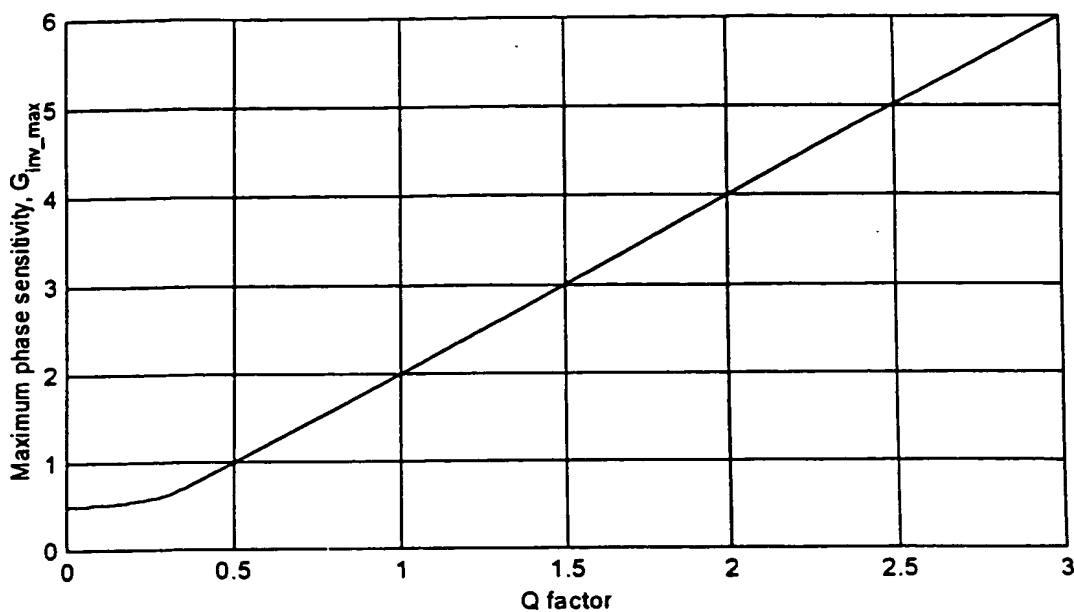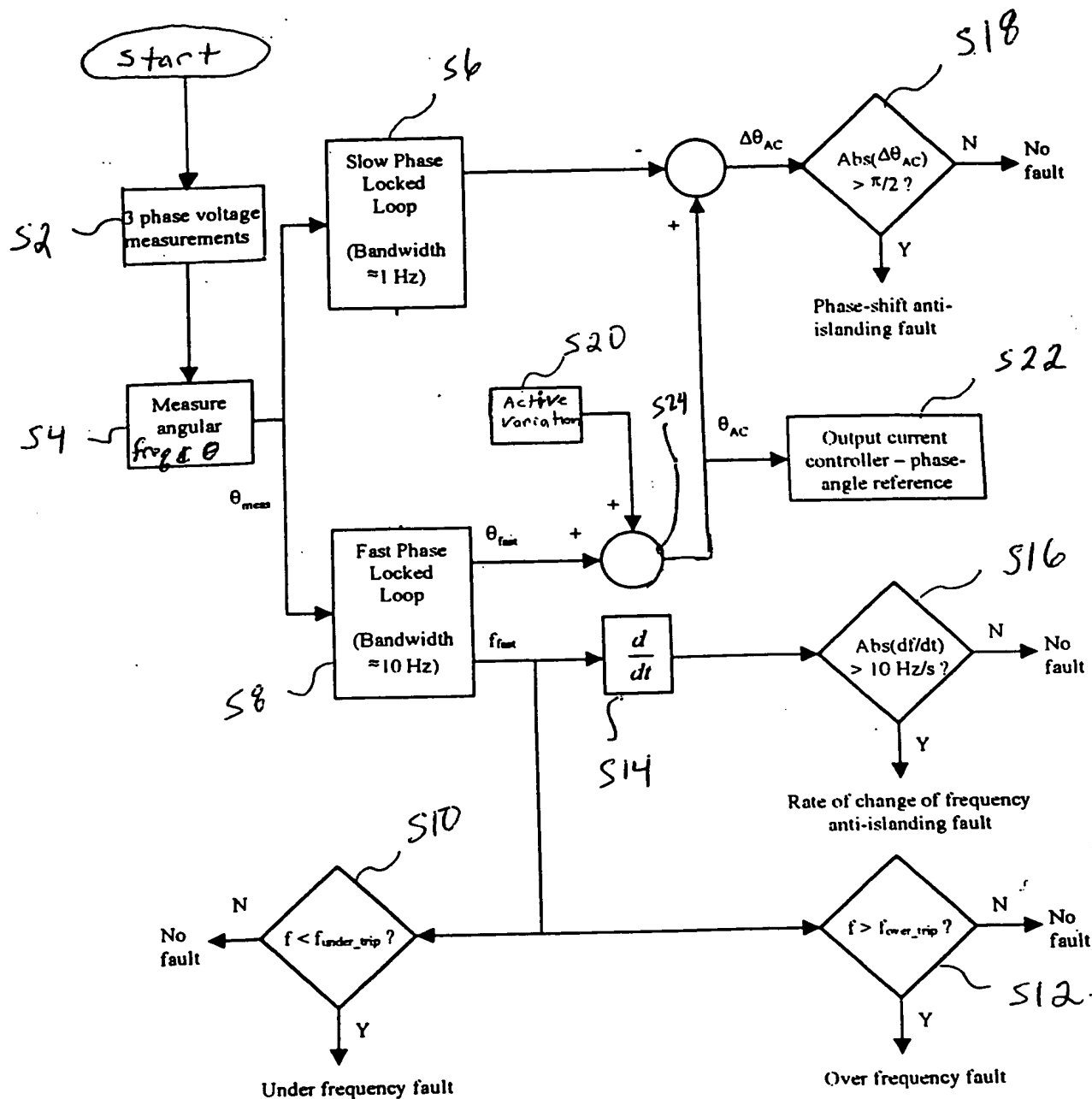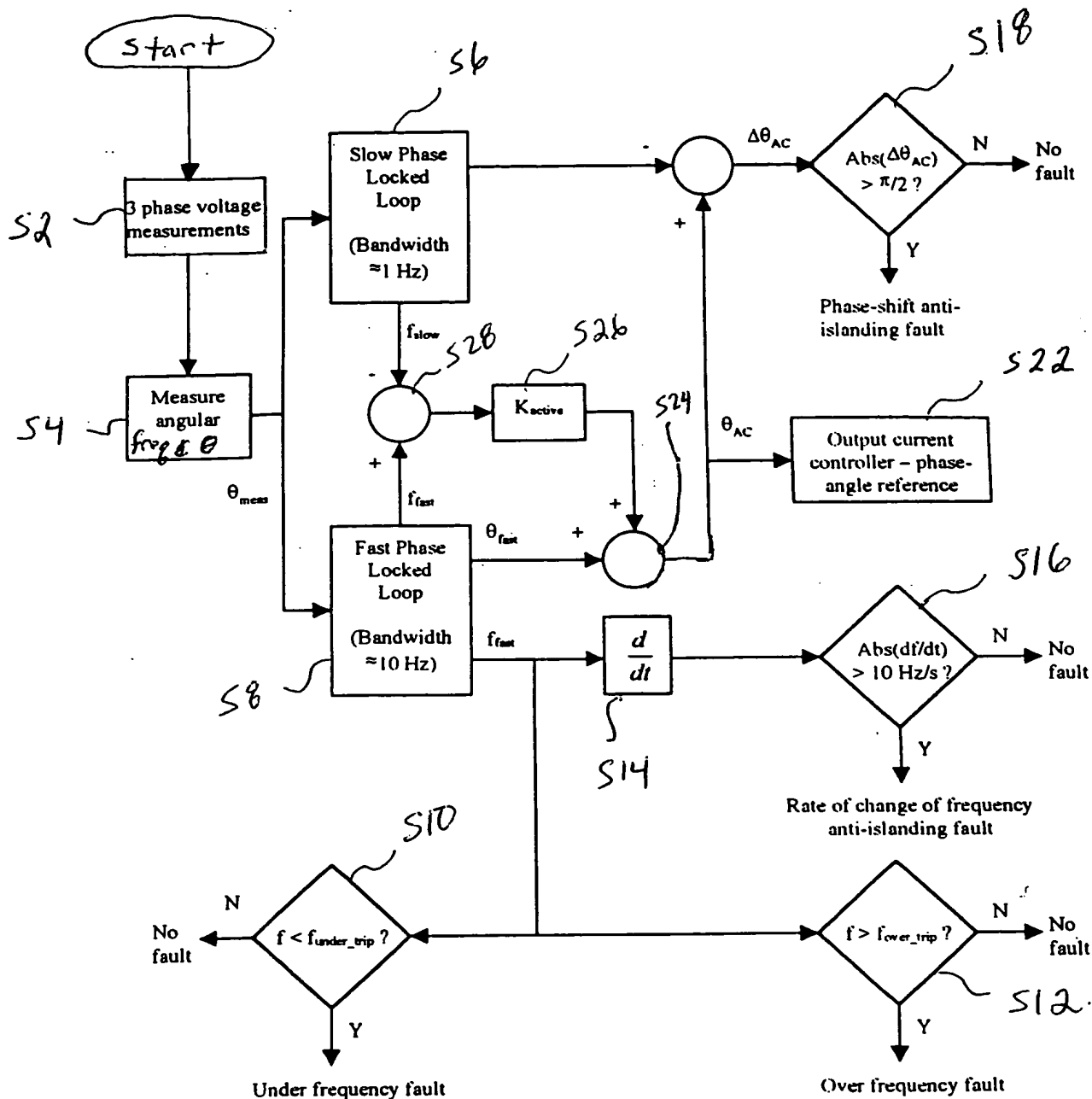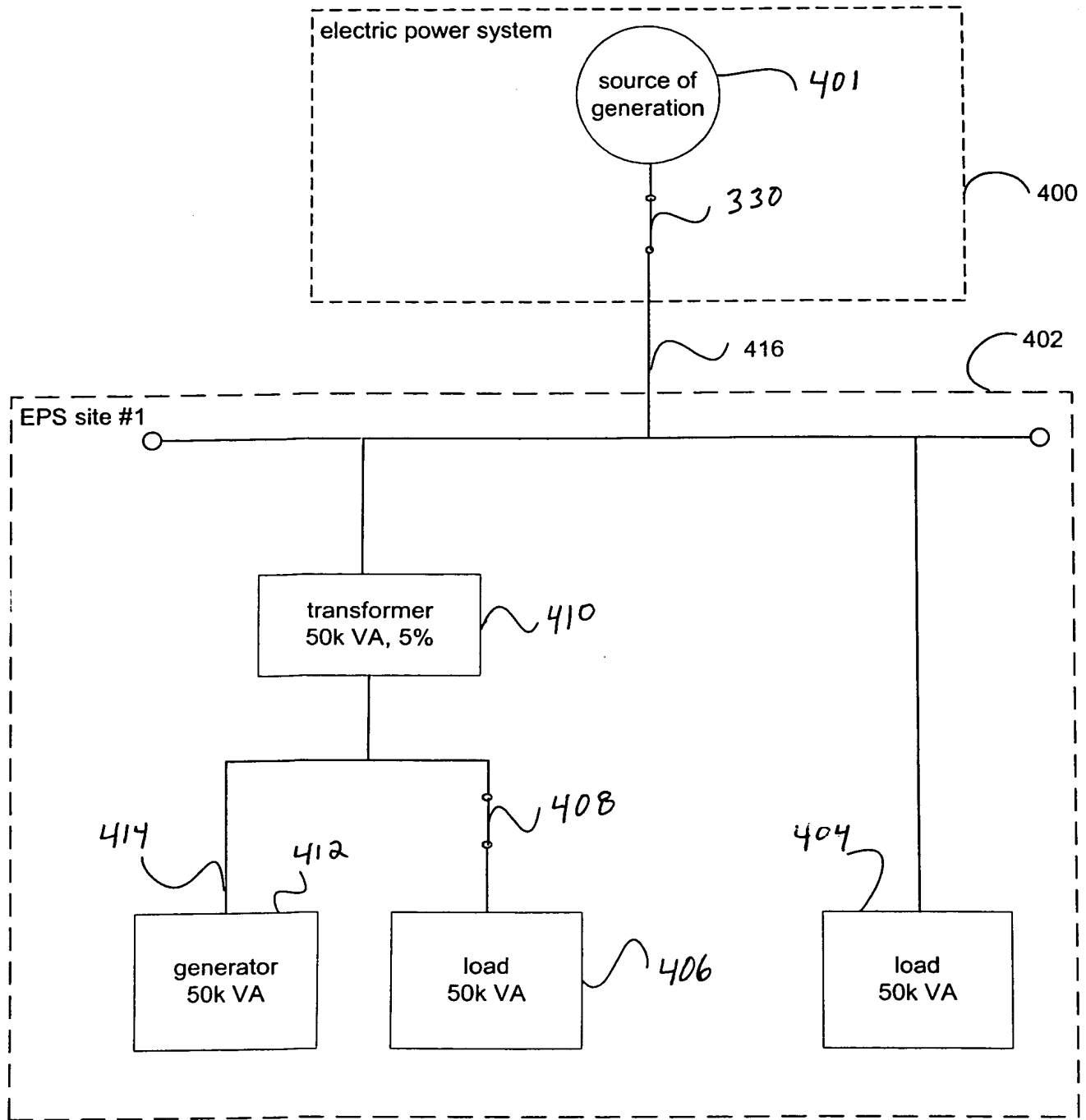|	
I_{POC_Island}	Islanded DR generator current magnitude at the POC (A)
V_{POC_Island}	Islanded voltage magnitude at the POC (V)
Z_{Island}	Impedance magnitude of the island looking into the POC (Ω)
ϕ_{Island}	Impedance phase-angle of the island looking into the POC (radians)
P_{DRG}	Demanded real power output of the DR generator (W)
Q_{DRG}	Demanded reactive power output of the DR generator (lagging is positive) (VAr)
θ	Angle output from the PLL (radians)
δ	Demanded current phase angle, $\delta = \tan^{-1}(Q_{DRG}/P_{DRG})$ (radians)

Figure 7

Figure 8

Figure 9A

Start

S2 — 3 phase voltage measurements

S4 — Measure angular freq & θ

θ_{meas}

S6 — Slow Phase Locked Loop (Bandwidth ≈ 1 Hz)

f_{slow}

S28

S26 — K_{active}

$-$ $\Delta\theta_{AC}$

S18 — Abs($\Delta\theta_{AC}$) > $\pi/2$? N → No fault

Y → Phase-shift anti-islanding fault

S22 — Output current controller – phase-angle reference

θ_{AC}

S24

S8 — Fast Phase Locked Loop (Bandwidth ≈ 10 Hz)

θ_{fast} f_{fast}

f_{fast}

S14 — $\dfrac{d}{dt}$

S16 — Abs(df/dt) > 10 Hz/s ? N → No fault

Y → Rate of change of frequency anti-islanding fault

S10 — f < f_{under_trip} ? N → No fault

Y → Under frequency fault

S12 — f > f_{over_trip} ? N → No fault

Y → Over frequency fault

Figure 9B

electric power system

source of generation ~ 401

330

400

416   402

EPS site #1

transformer
50k VA, 5%   ~ 410

414   412   408

404

generator
50k VA

load
50k VA   406

load
50k VA

Figure 10